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PALYNOFLORAL BIOSTRATIGRAPHY OF WELL AX, ONSHORE NIGER DELTA, NIGERIA

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Abstract

The Eighty -eight (88) ditch cutting rock samples from Well AX, between interval 5900 feet and 9000 feet were processed for palynomorphs using standard palynological sample processing procedures for their palynofloral contents for the purpose of establishing their biozonation, age and paleoenvironments. Lithologic description of the ditch cutting rock samples reveal that the sediments are mostly made of sandstone, with minor alterations of shale, mudstone, and siltstone as well as accessory minerals at some horizons. The shale is light grey, unconsolidated, sub fissile to fissile; the sandstone is made up of White to light grey, unconsolidated, well sorted, very fine grained to medium, sub-rounded to sub-angular grains while the mudstone is reddish and unconsolidated. The accessory minerals are pyrite and carbonaceous detritus, characteristically depicting Agbada Formation. Palynological analysis yielded ninety-six (96) well preserved miospores from which three biozones (Belskipollis elegans, Crassoretitriletes vanraadshooveni and Pachydermites diederixi zones were recognised and correlated with P740, P720 and P680 subzones of Evamy et al., 1978, respectively to assign early to middle Miocene age for the sediments. The abundance and diversity of terrestrially derived miospores and rare occurrence of marine derived types guided the interpretation of palaeo-environments in the studied section of the well AX. The sediments revealed fluctuations between continental/marginal marine to near shore/coastal deltaic paleo-environments.

Keywords: Palynomorph, Paleoenvironment, Age, Biozonation, Niger Delta, Palynology.

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Introduction

The Niger Delta Basin is an extensional rift basin in the Gulf of Guinea close to the coast of western Nigeria, on the passive continental margin with access to Cameroon, Equatorial Guinea, Sao Tome, and Principe (Michele et al, 1999). The basin is very complex with high economic values due to its active petroleum systems. Since the discovery of petroleum in the basin, exploration efforts toward more recovery have been intensified. Palynology has proven a useful tool in biostratigraphic characterization in Niger delta. Although numerous biostratigraphic researches have been done, results from such investigations are scarce in the public domain due to the hoarding of such information by oil companies operating in Nigera. Palynological investigation was carried out on eighty- eight (88) ditch cutting rock samples from interval, 5900 feet to 9000 feet of well AX, onshore Niger Delta (figure 1), for the purpose of age delineation and characterization of paleoenvironment of deposition of the rock succession.

STRATIGRAPHY OF THE NIGER DELTA BASIN

The stratigraphic boundaries of the surface limits of the three main formations that have been recognized within the basin (the Akata, Agbada and Benin) Formations have been studied by various authors (Reyment, 1965; Short and Stauble. 1967, Weber and Doukoru, 1975, Avbovbo, 1978, whiteman, 1982, Doust and Omatsola, 1989). These formations were laid under marine, transitional, and continental environments respectively, having age range from Eocene to Recent (Short and Stauble, 1967).

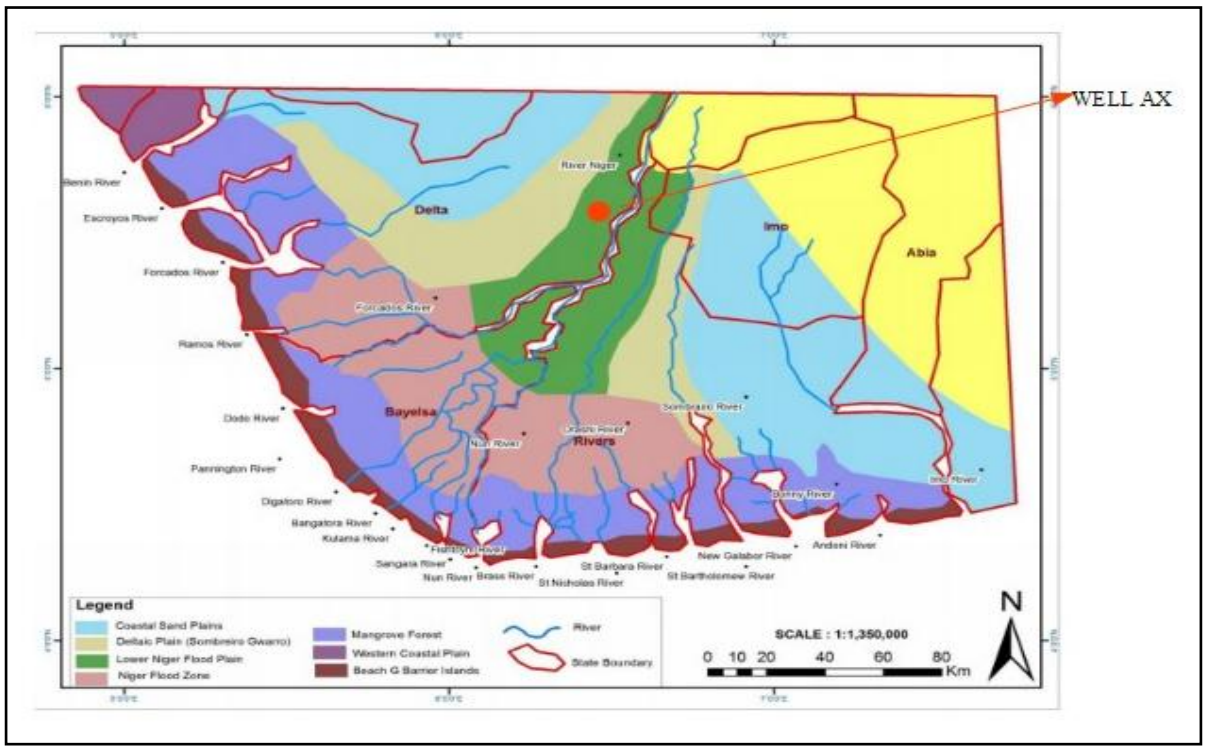

Figure 1: Location map of well AX field

The Akata formation**:** This is the delta's basal sedimentary unit. It is composed of over-pressured marine shales, sand-covered turbidites, and consistently dark grey channel fills. In deep-water circumstances, these turbidites could serve as reservoirs. It spans the Late Eocene to Recent Periods. According to Doust and Omatsola (1989), Whiteman (1982), and Corredor et al. (2005), the Akata formation's sedimentary thickness ranges from 2000 to 7000 meters. Since it is often rich

in organic debris, the Akata formation is thought to be the source of the hydrocarbon in the Delta (figure 2).

The Agbada Formation**:** This is the Niger Delta's main petroleum-bearing unit. It is underlain by the Akata Formation and is made primarily of sandstone and shale. It is a coarsening upward sequence of paralic to marine-coastal and fluvial-marine deposits. According to Corredor et al. (2005), the Agbada Formation can be distinguished by sand shale ratio into, the top, middle, and lower units with 60% to 40% sand, up 50% to 30% and 20% sand interbedded with under-compacted shale respectively. The Agbada Formation is the main deltaic section of the basin represented by the paralic siliciclastics that are more than 3500 m (11,500 ft) deep.

Benin Formation: The Benin Formation is made up of Late Eocene to Recent alluvial and upper coastal plain deposits that can be up to 2000 m (6600 ft) deep (Avbovbo, (1978), Aigbedion (2011) and Ajaegwu et al. (2012)). The majority of the formation is composed of sand, gravel, and back-swamp deposits. The Benin Formation which is the youngest of the three formations in the Niger delta overlies the Agbada Formation and is dated between the Oligocene and Recent epochs. Not much petroleum has been found in this unit but the sands are good aquifers, so represents the main water-bearing formation in the Niger Delta basin (figure 2).

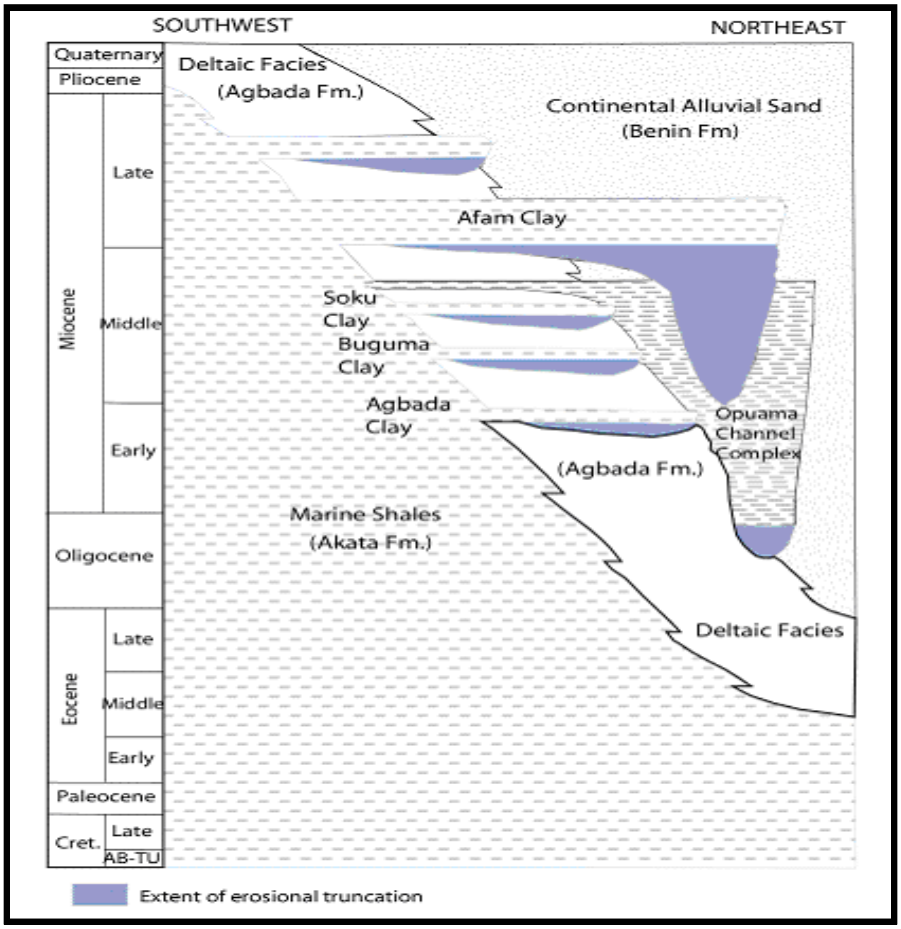

Figure 2: Lithostratigraphy of the Niger Delta (after Doust and Omatsola, 1989).

Previous work:

Palynological investigations in Nigeria are primarily restricted to the Tertiary Niger Delta. Since the discovery of crude oil at Oloibiri in the Niger delta in 1956, numerous studies on the region have been carried out by numerous authors, Although many of the specifics remain secret by oil companies prospecting for crude oil within the Niger delta basin, some important palynological reviews of the basin have been made. Evamy, et. al., 1978, established an informal palynological

zonation for the Niger delta based on numerical criteria. Soronnandi et al, (2014) in their research observed the Upper Cretacerous to Tertiary sediment of part of Anambra and Niger Delta basins from three exploration wells and outcrops located in the basins. Using the palynological sampling technique, the paleo-environment of deposition were determined to range from lithoral to proximal offshore in a shallow marine setting.

Aturamu et al, (2015) conducted their investigations on NEP -1 well, Eastern Niger Delta, utilizing thirty-six composite ditch cutting well samples from the Agbada Formation and erected three (3) palynological zones (*Foveotricolporites sp., Psilatricolpitesokezeis*, and *Echiperiporites cf. estalae)* which were used to ascribe geologic ages ranging from the late Miocene to the early Pliocene.

Manuemelula et al, (2019) conducted palynofacies analysis of Meren field and delineated five palynofacies and used it to characterize the environment as follows; palynofacies I: fluvio-deltaic and moderately distal oxic environment, palynofacies II: nearshore dysoxic-anoxic environment, palynofacies III: marginal marine under a proximal dyoxi-suboxic environment, palynofacies IV: non-marine or nearshore environment under oxic conditions, and palynofacies V: fluvio-deltaic/nearshore (proximal shelf) under oxic condition with the age ranging from Early to Late-Miocene age. Amiewalan and Balogun (2021) conducted research on the GZ-1 well from the onshore western Niger Delta in order to identify newly observed developments in the types of important pollen and spore taxa that have shorter and more distinct interval zones. Palynological analysis produced a high yield in a variety of rich and varied palynomorphs. Several zones were identified ranging from AF1 *Psilatricolporites crassus* zone, AF2 *Verrucatosporites usmensis* zone, AF3 *Triplochiton scleroxylon* zone, AF4 *Crassoretitriletes vanraadshooveni* zone, AF5 *Acrostichum aureum* zone, AF6 *Gemmatriporites ogwashiensi*s zone and AF7 *Retitricolporites irregularis* zone zone with the age ranging between Early Oligocene to Early Miocene.

Tejumade (2022) carried out palynological analysis of samples from AA-1 Well in the Niger Delta. The diagnostic forms recovered permitted the zonation and dating of the analyzed section with results showing the section broadly assigned to the P520, P480 and P470 palynological zones.

Methodology

Laboratory Analysis

The Eighty -eight (88) ditch cutting well samples from Well AX, between interval 5900 feet and 9000 feet were processed in the laboratory using the standard palynological sample preparation method. Well log signatures, sand/shale ratios, textural properties, and accessory mineral compositions of the rock samples where available aided the lithostratigraphic analysis.

The samples were treated with concentrated organic acids (5% HCL, 60% HF, and HNO3) in order to break down the rock sample matrix, separate heavy liquids, and oxidize the samples to maximize potential recovery of organic matter. This allowed for the complete digestion and separation of all inorganic matter of the rock samples and produced the greatest amount of the insoluble organic matter. 25g of the samples were initially treated with 10% HCL to dissolve the carbonates, present in the samples, while 60% HF was added to dissolve silicates, then 5% HCL was added to the mixture to eliminate the silicofluoride gels that have formed in the samples due to the reaction of HF and HCL. After separating the palynomorphs from the residue, HNO3 was added to highlight their distinctive characteristics. Distilled water was added with a pipette and allowed to stand for a while. it was twice decanted and then transferred from the glass beaker to the cover slip. One or two drops of Norland glue was applied at the centre of the slide on the hot plate in order to enable it it spread out and reach the size of the cover slip. Using a picking pin to prevent air bubbles from forming, the cover slips and their contents were delicately placed onto the glass slide containing the mounting media before being given some time to dry in the sun. After drying, the slides were

mounted on a biological microscope (light transmitted type), where the various sporomorphs were observed, recognized, tallied at various depth intervals and recorded. The biostratigraphic analysis program software "STRATABUG" was used to input all the information pertaining to the identification and counting of palynomorphs at the specie and sub-species levels, producing a distribution chart and compared with the standard palynological zonation scheme of Evamy et al, (1978), for the purpose of age determination as well as paleoenvironmental characterization.

RESULTS AND DISCUSSIONS

Lithostratigraphy: the lithologic analysis of the ditch cutting rock samples revealed that the sediments are composed of mainly sandstone with minor alternations of shale, mudstone, and siltstone and accessory minerals at some horizons. The sandstone is White to light grey, unconsolidated, highly sorted, very fine grained to medium, sub-rounded to sub-angular grains; the shale is composed of Grey to light grey, unconsolidated, sub fissile to fissile grains. The mudstone is brownish and unconsolidated, and the accessory minerals are pyrite and carbonaceous debris (figure 3). These characteristics typify the paralic Agbada Formation.

PALYNOFLORAL ZONATION AND AGE CHARACTERIZATION

Palynofloral Zonation: Three (3) palynofloral Zones were delineated, summarized in (Table 1) and described as follows:

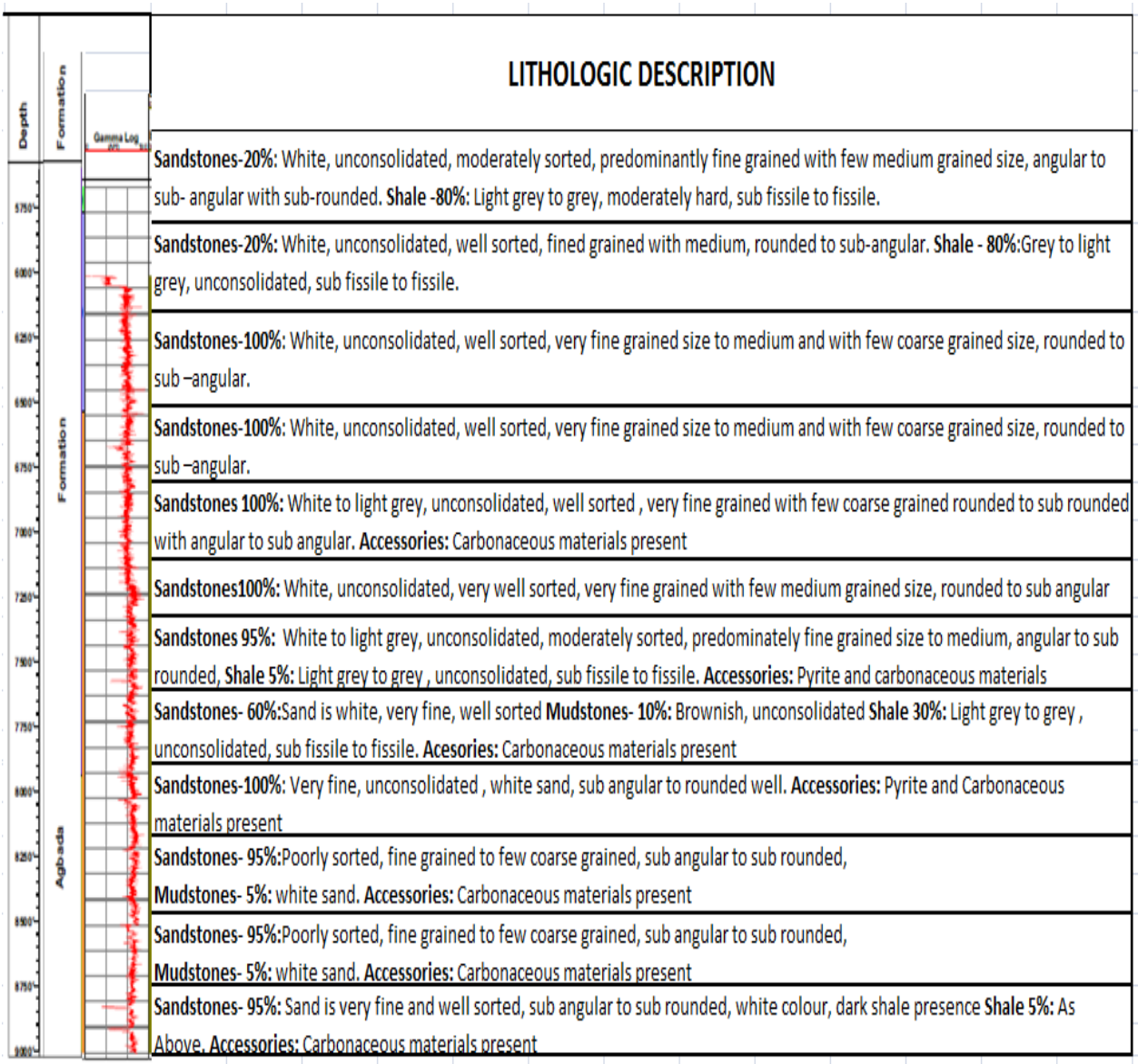

Figure 3: lithostratigraphy of well AX,

Zone 1: *Belskipollis elegans*
Interval: 5600– 5700 feet
P-zone: P740
Age: Middle Miocene

This Interval defined by the top rich occurrence of *Belskipollis elegans and* Common occurrences of *Verrutricolporites rotundiporus* and *Racemoncolpites hians.* The top of the zone correspond to the overlying base of P770 marked by Quantitative Top (QT) of *Belskipollis elegans* at 4528 feet, abundant occurrence of *Zonocostites ramonae*, *Verrucatosporites* spp, *Verrutricolporites rotundiporus*, *Racemoncolpites hians* and *Crassoretitriletes vanraadshooveni*. This interval is further characterized by the dominance of *Zonocostites ramonae* assemblage in association with *Verrucatosporites* spp., *Acrostichum aureum*, *Psilatricolporites crassus*, *Verrutricolporites rotundiporus*, *polypodiaceoisporites* spp., and *Racemonocolpites hians* in association with low counts of *Monoporites annulatus*, *Pergrinipollis nigericus* and *Numulipollis neogenicus*.

The base of the zone is marked with Quantitative Base (QB) of *Belskipollis elegans* at 5700ft.

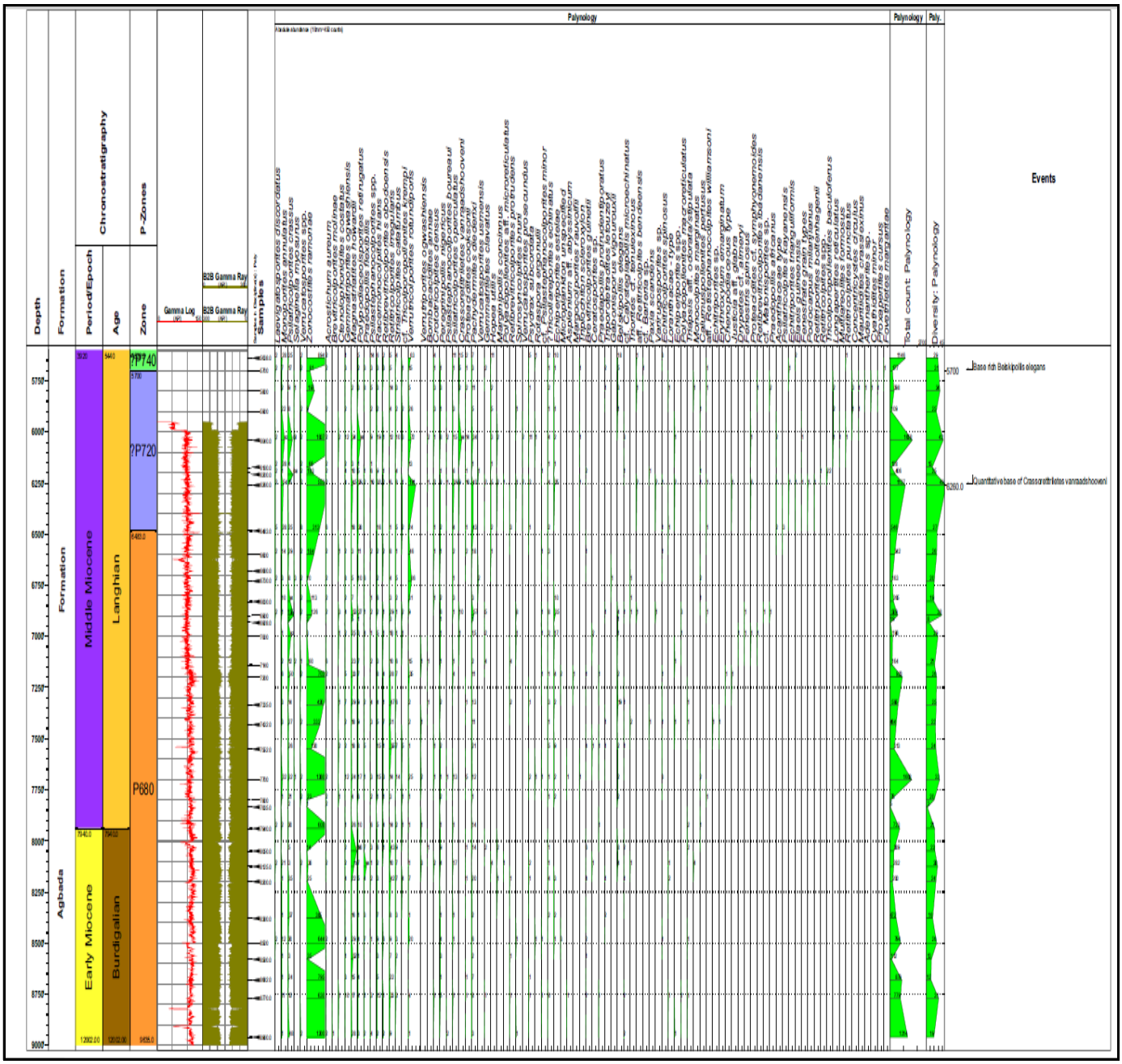

Figure 4: Distriburion chart of Palynomorphs in Well AX.

zone 2: *Crassoretitriletes vanraadshooveni*
Interval: 5700 – 6483ft
P-zone: P720
Age: Middle Miocene

The top of this zone correspond to the overlying base of P740 marked with Quantitative Base (QB) of *Belskipollis elegans* at 5700 feet. The zone is characterized by moderate abundance of *Racemonocolporites hians, Retitricolporites* spp, *Belskipollis elegans, Verrucatosporites rotundiporus, Monoporites annulatus, Zonocostites ramonae, Acrosticulum aureum;* Moderate to common occurrence of *Verrucatosporites* spp., *Laevigatosporites* spp., *Psilatricolporites crassus, Acrostichum aureum, Zonocostites ramonae Striatricolporites catatumbus* and rare *occurrence of Pachydermites diederixi* and *Echiperiporites estelae.* The base of the subzone is marked with base occurrence of *Crassoretitriletes vanraadshooveni* at 6483 feet.

Zone 3: *Pachydermites diederixi*
Interval: 6483 – 9635ft
P-zone: P680
Age: Early/Middle Miocene

The top of P680 corresponded to the overlying base of P720 marked with base occurrence of *Crassoretitriletes vanraadshooveni.* The base is defined by the quantitative occurrence of *Pachydermites diederixi, Psilatricolporites crassus* and *Acrostichum aureum*.

The interval is characterized by the co-occurrences of *Pachydermites diederixi, Psilatricolporites crassus, Retitricolporites irregularis, acrostichum aureum, Laevigatosporites* spp. Other important forms present are *Crassoretitriletes vanraadshooveni, Ctenolophonidites costatus, Peregrinipollis nigericus, Striatricolpites catatumbus, Echiperiporites estalae, Psilastephanocolporites sp., Retibrevitricolporites obodoensis, Verrucatosporites* spp. *Laevigatosporites* spp., near base appearance of *Racemonocolpites hians* and rare occurrence of *Monoporites annulatus*.

AGE CHARACTERIZATION: The miospore zones delineated from Well AX were compared with t Germeraad et al. (1968) and Evamy et al, 1978 zonation schemes and used to characterize the age of the well within the sample interval.

The analysed section of the well (5600 – 9000 feet) penetrated palynological zones, p700 (middle miocene) and p600 (early miocene) of evamy et al. (1978). This correspond to *Echitricolporites spinosus* (Middle-late Miocene) and *Magnastriatites howardi / Crassoretitriletes vanraadshooveni* (Early Miocene) zones of Germeraad et al. (1968). The palynological subzones (P680, as well as P720 and P740) were also recognised based on their palynofloral characteristics.

The boundary between P770 and P740 is marked with Quantitative Top (QT) of *Belskipollis elegans* at 4528 feet, while the P740 and P720 boundary is tentatively marked with Quantitative Base (QB) of *Belskipollis elegans* at 5700 feet. The top of P680 which corresponded with base of P720 was marked at the interval below LDO *Crassoretitriletes vanraadshooveni* at 6483 feet while the base of the P680 subzone is bounded at the base by the Terminal Depth (Table 1).

Table 1: summary of the Palyno-stratigraphy of Well X

Depth Interval (ft)	**Palynomorph Zones (Evanmy)**	**Period/Epoch**	**Age**	**Palynomorph Bio-Events / Remarks**
5600 – 5700	**P740**	**Middle Miocene**	**Langhian**	Base rich Beskipollis elegans
5700 – 6500	**P720**	**Middle Miocene**	**Langhian**	Base of Quantitative base of Crassoretitriletes vanraadshooveni
6500 - 9000	**P680**	**Middle Miocene/Early Miocene**	**Langhian/ Burdigalian**	Terminal Depth

PALEOENVIRONMENTAL SYNTHESIS:

The abundance and diversity of miospores with terrestrial origins and the rarity of those with marine origins in the examined portion of well AX served as the basis for the interpretation of palaeoenvironments. The sediments showed transitions between near shore/coastal deltaic and continental/marginal marine paleoenvironments.

The continental/marginal marine paleo-environment is indicated by the abundance and high diversity of miospores co-occurring with rare to non-occurrence of marine derived palynomorphs within the studied interval (5600 – 9000 feet) of well AX. The palynofloral assemblage is characterized by the common occurrence of forest species such as *Pachydermites diederixi* and *Retitricolporites irregularis*; common to abundant occurrence of mangrove miospores such as *Psialtricolporites crassus* and *Zonocostites ramonae*; common occurrence of savannah miospores such as *Monoporites annulatus*, *Retibrevitricolporites obodoensis* and *Retibrevitricolporites protudens*. Other miospores suggestive of continental/marginal paleoenvironment include common occurrence of *Verrutricolporites rotundiporus* and *Magnastriatites howadii* with rare occurrence of foraminiferal test lining and dinoflagellate cysts.

Abundant occurrence of *Zonocostites ramonae* indicates coastal deposition close to source. The common occurrence of *Crassoretitriletes vanraadshooveni*, *Verrucatosporites usmensis* both climbing ferns pointed to swamp forests, while *Magnastriatites howard i*ndicate freshwater influence.

SUMMARY AND CONCLUSION:

The Eighty -eight (88) ditch cutting rock samples from Well AX, between interval 5900 feet and 9000 feet were processed for palynomorphs using standard palynological sample processing procedures. Lithologic description of the ditch cutting rock samples reveal that the sediments are mostly made of sandstone, with minor alterations of shale, mudstone, and siltstone as well as accessory minerals at some horizons. The shale is light grey, unconsolidated, sub fissile to fissile; the sandstone is made up of White to light grey, unconsolidated, highly sorted, very fine grained to medium, sub-rounded to sub-angular grains while the mudstone is reddish and unconsolidated. The accessory minerals are pyrite and carbonaceous detritus characteristically depicting Agbada Formation. Palynological analysis yielded ninety-six (96) well preserved miospores from which three biozones (B*elskipollis elegans*, C*rassoretitriletes vanraadshooveni* and P*achydermites diederixi zones* were recognised and correlated with P740, P720 and P680 subzones of evamy et al., 1978, respectively to assign early to middle Miocene age for the sediments. These zones also correspond to the *Echitricolporites spinosus* (Middle-late Miocene) and *Magnastriatites howardi / Crassoretitriletes vanraadshooveni* (Early Miocene) zones of Germeraad et al. (1968). The abundance and diversity of terrestrially derived miospores and rare occurrence of marine derived types guided the interpretation of palaeo-environments. The sediments revealed fluctuations between continental/marginal marine to near shore/coastal deltaic paleo-environments. The continental/marginal marine paleo-environment is indicated by the abundance and high diversity of miospores co-occurring with rare to non-occurrence of marine derived palynomorphs within the studied interval while the abundant occurrence of mangrove pollen, *Zonocostites ramonae* indicated the coastal environment close to the source.

In conclusion, the studied interval of well AX penetrated the Agbada formation during the early to middle Miocene age in an environment ranging from continental and marginal marine to coastal deltaic paleoenvironments.

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